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Cultural Experiments With Yellow Bermuda Onions Under Irrigation

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

T. O. WALTON, President

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In this bulletin the factors that bear on the yield of onions are discussed—namely, size of plant at transplanting time, rate of seeding the seed bed, distance apart of rows, pruning, frequency of irrigation, and fertilizer placement.

A seeding rate of 17 pounds per acre gave sufficient plants to set 10 acres in 14-inch rows, and resulted in 45 to 50 per cent of medium sized plants. Less seed does not produce a profitable number of plants. More seed results in too many small plants. Medium sized plants are the most dependable. Large plants may give higher yields but usually result in too many splits, doubles, and seed stems. Transplanting gives better yields than direct field sowing, as will a 14-inch spacing of rows compared with a 16-inch spacing.

When irrigation immediately follows transplanting, yields will normally be decidedly higher than where irrigation is delayed 10 days or so. Over-irrigation should be avoided as it usually reduces the yield. After they begin to bulb, onions respond to more frequent irrigations than before. In years of severe thrips infestation they need more frequent irrigation throughout the season.

The placing of a 4-inch band of fertilizer in a shallow furrow below the ridges in which the onions are placed resulted in higher yields in each of 3 years than the same amount of fertilizer broadcast.

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CULTURAL EXPERIMENTS WITH YELLOW BERMUDA ONIONS UNDER IRRIGATION

By Leslie R. Hawthorn, Horticulturist,
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Cultural practices other than the application of fertilizers have been found to affect very materially the production of onions in the Winter Garden. As the culture of onions under irrigation is rather intensive, the cost of growing such a crop is higher than with most vegetables. The Station has therefore attempted to determine whether or not these practices can be improved, so that growers may benefit by the most efficient methods available. Results of tests with fertilizer have already been published (2).*

Most growers clip their plants at transplanting time; likewise they claim to prefer the "pencil sized" plant for transplanting, yet usually their seed-beds have been sown so thickly that a large proportion of the plants are smaller than this. Some growers space the rows at 16 inches, some at other distances. In some sections, sowing the seed directly in the field is the common practice, while in others transplanting is preferred. Some growers irrigate as soon as possible after the onion plants are set out, others purposely delay irrigation a week or longer. There is a question, too, as to how frequently onions should be irrigated. These and other questions the Station has attempted to answer during the last five years. This bulletin therefore supplements the previous work on fertilizers by indicating various cultural practices which may be used in combination with the fertilizer practices suggested two years ago.

Review of Other Work

In Colorado experiments in which transplanting was compared with field sowing resulted in the conclusion that "transplanting of onions under ordinary conditions probably does not pay in the Rocky Ford district, yields were less than with the field-sown onions, and costs were considerably greater" (1). The Valencia variety was presumably used in these experiments.

Spacing experiments have been conducted in California (3), Utah (10), and Montana (7). Those in California were carried from 1929 to 1937, inclusive, with the California Early Red variety and involved the spacing of seedlings at distances of 3, 4, 6, 8, and 12 inches apart in rows spaced 18 inches. The results showed that, "as the space between plants in the row was increased from 3 to 12 inches there was a delay in the time of maturity, an increase in the size of bulbs, and a decrease in the yield per acre." In Utah in 1932 the Utah Valencia variety was sown and then later thinned to stand 2, 4, 6, 8, and 10 inches apart in rows 16 inches apart. Yields were reduced by thinning, and practically in proportion to

*This and similar numbers refer to references under "Literature Cited."

the distance of the thinning. When spaced greater than 4 inches the percentage of large bulbs decreased, and the numbers of doubles and scallions increased. Spacing experiments with the Sweet Spanish (Valencia) variety were conducted in Montana for five seasons ending in 1934-35. The seedlings were transplanted to distances of 3 and 6 inches in the row. Every year the wider spacing resulted in larger onions, the bulbs weighing on the average 2.8 ounces more than those from the 3-inch spacing. Acre yields, however, were greater from the plats with the smaller spacing.

In California from 1927 to 1929, inclusive, small and large seedlings of the California Early Red onion were planted in comparative treatments to determine the effect of the size of plant on yield (3). This experiment was combined with a time of planting test so that each year there were a number of these plantings comparing the small and the large plants. In all of these tests in all three years "the large seedlings produced a higher yield of bulbs and the average size of the bulbs was larger."

A preliminary report on frequency of irrigation experiments in Texas was published in 1934 (5). This report emphasized the technique particularly, but in so doing offered data which indicated that frequency of irrigation is an important factor in onion production, and that while at certain periods of growth more frequent irrigations are likely to be desirable, too frequent irrigation is in general undesirable. The data presented in this preliminary report are given again in this publication in order that they can be further discussed in the light of results secured during the following seasons.

Placing fertilizer in bands in various locations adjacent to the row has received considerable attention in recent years. Experiments too numerous to mention have been reported from many sources and on many crops. Fertilizer placement in connection with vegetable crops has been carried out particularly in New York (8), Virginia (11), and New Jersey (6). In the last mentioned state onions were included in the 1935 experiments. When the fertilizer was placed in a band 3 inches below where the onion sets were planted, definitely greater yields were obtained than where the same fertilizer was broadcast.

Method of Procedure

In so far as possible the procedure in all these experiments conformed with commercial practices. Only the factor being tested was varied. Because of the fairly large number of treatments, and because one or another of them affected cultural practices all the way from seeding up to harvest time, it was not possible always to compare the plats in one experiment with those in another. Perhaps through necessity one set of plats was planted earlier than another, or on a different piece of ground, and perhaps for the same reason they were irrigated on different days. Some experiments were started in an earlier year than others and as a result have been subjected to a slightly different procedure from that applied to experiments started in later years. Thus the accounts of the procedure in the various experiments are in general similar, one procedure varying from another only in certain minor details. It is sufficient to say that, of course, in any one experiment and in any one year all treatments were handled just as nearly alike as humanly possible, except for the one factor being tested.

Some general statements can be made about most of the experiments. With the exception of the frequency of irrigation, direct field sowing vs. transplanting, time of planting, and one treatment in the width of row tests, all experimental material was planted in plats 100 feet long and consisted of five rows 14 inches apart. After two feet had been removed at harvest time from each end of the plat, the three center rows were harvested for the records. This area on which data were based was a trifle larger than 1/130 of an acre. After the first two years a three-foot raised border separated each of the plats. Because the land used for these experiments was terraced and usually of an irregular shape, the plats could not be arranged in regular tiers and blocks, but often had to be grouped in strings of anywhere from 2 or 3 plats to several dozen. The location of the experiments was changed every year, although the general soil type—Webb fine sandy loam, and Crystal sandy loam—remained the same from year to year. Previous to the 1935-36 season there were three replications of each treatment. Beginning with that season the replications were increased to four.

The frequency of irrigation experiments were planted in plats 109 feet long consisting of five rows 16 inches apart. The three center rows harvested for records gave an area of 1/100 acre.

All the cultural experiments (excluding the fertilizer placement experiment) were fertilized uniformly with 900 pounds per acre of 6-12-0 fertilizer. This was broadcast several days previous to planting.

The differential treatments in each of the experiments were handled in the ways described below.

Clipping the Plant: At the time of transplanting from the seedbed to the field, plants or seedlings were handled in one of the four following ways: (a) left unpruned, (b) tops pruned, (c) roots pruned, (d) both tops and roots pruned (see Fig. 1). In the second and fourth treatments the man pulling the plants, as soon as he had a fair handful, would wring off about half of the tops with a quick twist of his hands. This is the common procedure in commercial practice. The roots in the third and fourth treatments were cut with shears. On the whole they were trimmed fairly close to the root plate.

Size of Plant: No commercial grower grades his plants for size, but of course variation does exist in size of the plants as a whole. In order to obtain more specific information as to the effect of each plant size on the final field, plants were carefully graded into three sizes: small, medium, and large (see Fig. 4.). Since literally thousands of plants had to be so graded each year it was impractical to measure every one; hence they were graded by eye. Afterwards random samples were taken for measurement and weight. A record of the size of the plants used in each of the five years is given in Table 1.

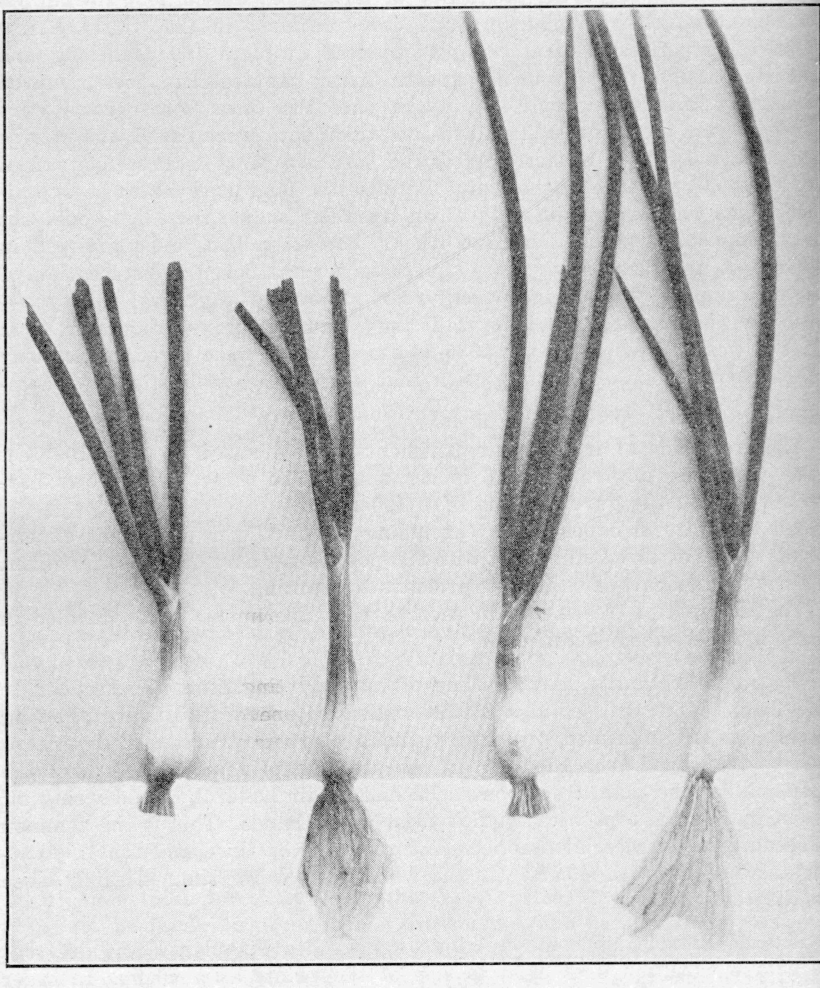

FIG. 1. Plants used in pruning experiment. From left to right the plants are: tops and roots both pruned; tops only pruned; roots only pruned; no pruning.

Table 1. Weight and dimensions of plants used in size of plant experiment from 1932-33 to 1936-37

Season	Size of plant	Weight of 100 plants (gm.)	Neck diameter (mm.)	Height of unpruned plant (cm.)
1932-33:				
	small	116	3–4	11–15
	medium	187	5–7	17–23
	large	.433	7.5–9	28–36
1933-34:				
	small	160	3–5.5	9–16
	medium	620	6–9	18–25
	large	1330	10–13	28–36
1934-35:				
	small	173	3.5–5	20
	medium	563	7–9	27–30
	large	1108	10–12	30–34
1935-36:				
	small	189.5	2–5	20–26
	medium	538.8	6–9	33–36
	large	1069.0	10–15	39–50
1936-37:				
	small	203	2–6	18–22
	medium	688	7–9	25–33
	large	1195	10–13	40–50

Rate of Sowing: A rate of sowing experiment was started as a result of the size of plant test. Since it soon became apparent that whatever the results of that test turned out to be, it would be impractical in any case to grade the plants in commercial practice, factors affecting size of plant in the seed became important. By finding out how the rate of seeding affected the size of plant at transplanting time, we would be in a position to know what rate is most desirable from the point of view of the size of plant. Since there was available no equipment which would accurately predetermine a definite and desired rate of seeding, various plats had to be seeded at rates which were obviously different, but which were not exactly known until after they were completed. This worked out rather well, except that no two years' treatments were exactly alike. Table 5 lists the treatments and rates applied each year.

To determine the number of plants in an acre, five random counts were made on distances up to 30 feet, and the number per acre calculated from an average of these counts. Similarly random lots of 100 plants each were weighed to obtain the weight. From two such lots out of each treatment, counts were obtained on the numbers of plants of the various sizes.

Direct Field Sowing vs. Transplanting: In the first season of this test the seed was sown on the same day (September 19) in both the seedbed and the field. This is about the normal time to plant onion seedbeds in the Winter Garden area. Since the results the first year indicated that seed should not be sown so early directly in the field, the plats involving this treatment were not planted in following years until a month later. The rate of sowing in the field was adjusted so that the stand obtained would, as nearly as possible, be thick enough to correspond fairly well with the transplanted treatment, and at the same time not thick enough to necessitate thinning. Obviously this is one of the difficulties of direct field sowing, and as such is given further attention later in the discussion of the results.

Width of Row: Only two widths were compared, 14 inches and 16 inches.

Frequency of Irrigation: Treatments in this experiment were based on three and, after the first year, on four definite accumulations of evaporation. These were: 0.75, 1.25, 1.75, and 2.25 inches. The first three treatments were tried in the first season, 1931-32. In the following seasons there were six treatments. Besides the four accumulations listed above, a set of plats being irrigated at the 1.75-inch rate, and another being irrigated at the 2.25-inch rate, were changed to 1.25 inches when the bulbs began to form.

The time at which a treatment was irrigated was determined from the rainfall and evaporation records. From the daily records of the official evaporation tank (read to .001 inch) it was a simple matter to keep a record of the total evaporation starting from any given date. As soon as this accumulation reached 0.75 inch, the plats assigned to this treatment were irrigated, and a new record of accumulation for this treatment started. Other treatments were handled in the same way, each according to the accumulation called for. All treatments were of course irrigated at the time of transplanting, and evaporation records were kept from that date to determine the time of the second irrigation for each treatment. In case of light rainfall, it was taken into account in the evaporation records, but if the rainfall amounted to 0.5 inch or more it was arbitrarily called an irrigation and accumulations of daily evaporation began again for all treatments.

Delayed Initial Irrigation. In this experiment there were three treatments the titles of which practically explain themselves. They were: (1) immediate irrigation (i. e., the same day as the onion plants were set out); (2) irrigation delayed; and (3) planting delayed but then immediate irrigation. The delay in treatment No. 2 was normally 9 to 10 days, usually the latter. On the same day that this delayed irrigation was carried out, the plats in the third treatment were planted and irrigated at once. The plants in all of these treatments were pulled from the seedbed on the same day (the day treatment No. 1 was planted), and those put in the plats of the third treatment were stored in the barn or laboratory pending the time of planting.

Fertilizer Placement: *In those plats in which the fertilizer was "placed,"* a special homemade marker having 5 wooden prongs each 4 inches wide was used to make a shallow furrow, 1 to 2 inches deep, below the place where the onions were to be planted later (Fig. 2). The fertilizer was then scattered by hand along these furrows, and the ridges over them were made with a marking cultivator. The 6-12-6 fertilizer was applied in each treatment at the rate of 600 pounds per acre. This particular application

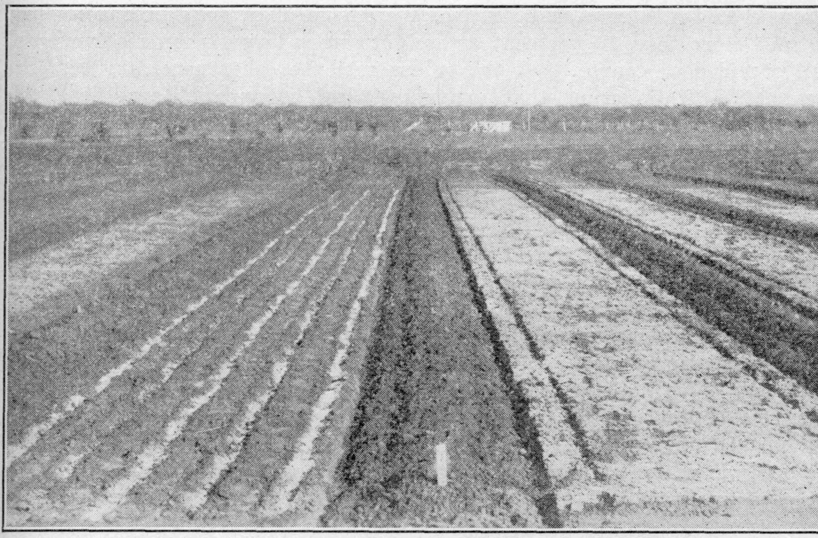

FIG. 2. Placement versus broadcasting of fertilizer. In the plat on left the fertilizer has been scattered along the shallow furrows over which were later made ridges in which the plants were set. In the plat on the right the same amount of fertilizer has been broadcast.

was used because it was the key treatment in the fertilizer experiments previously reported (2). As shown in the report of those experiments, applications involving different amounts than 600 pounds as well as different formulas are usually more profitable, and hence the use of this amount and this formula in the "placement" experiment should not be taken as indicating that such an application is always the most desirable.

EXPERIMENTAL RESULTS

The following groups of experiments are concerned chiefly with the manner in which the crop is handled from the time the seed is sown up to and including the time the plants are transplanted from the seedbed. It is interesting to note that a number of the treatments tried in these experiments and at a time when the onion plants were still young produced results which were significant and recordable fully four months later. In other words it is evident that yields and quality do not entirely depend on the four months of care which the onions receive after they are set in the field, but on the way in which they are handled in the seedbed and at transplanting time as well.

Yields have been recorded in two ways: in terms of U. S. No. 1 onions, jumbo and medium sizes combined, and also as total yield. Normally under any conditions there are more U. S. No. 1 onions of medium size than there are of any other grade, and from the market point of view this is by far the most important grade. However, according to the standards established by the United States Department of Agriculture a bushel of onions would still rate as U. S. No. 1 grade medium sized onions so long as "not more than 10 per cent by weight" were larger than medium size, and provided of course, that the onions met the other necessary requirements (9). This means that under practical commercial conditions the onions of jumbo size are usually salable along with the U. S. No. 1 mediums and at the same price. Hence the inclusion of this grade in the yield of U. S. No. 1 onions seemed a desirable record.

Pruning the Plant

For some reason or other the effect of pruning on yield was greater and perhaps more clear-cut the first year than it has been in any succeeding year (Table 2). Viewed statistically few significant results have been obtained from this experiment. All treatments, except the one in which tops and roots have both been pruned, have exceeded the other treatments in one year or another. In the first year the plats in which the plants were not pruned outyielded by over 120 bushels of U. S. No. 1 onions per acre the plats in which the tops were cut back. This was a significant difference and the experiment that year seemed to point in a very definite direction. However, the very next year the treatment in which the tops only were pruned, outyielded all other treatments. This result was repeated in 1935, although the other treatments lined up somewhat differently.

On an average for the five seasons, plants which had their tops removed yielded 258 bushels of U. S. No. 1 onions per acre and a total per year of 335 bushels, as compared with 260 bushels of U. S. No. 1 onions and a total yield of 334 bushels for plants on which the roots had been removed. In the plats where there was no pruning, the yield of U. S. No. 1 onions was 279 bushels, and for the total, 354 bushels.

During the five seasons of this experiment the treatment in which the plants have had both tops and roots pruned back, has resulted in yields which ranked the treatment in either third or fourth place each year (Table 3). In contrast to this, the treatment, in which the plants received no pruning at all, ranked in either first or second place four times out of the five years. In 1935 it ranked third.

Comparing the yields of U. S. No. 1 grades of these four treatments over the five-year period according to Love's modification of Student's method (4), we find odds of 3.27 to 1 that pruning the tops only have given higher yields than pruning both tops and roots; odds of 9.8 to 1 that higher yields were obtained without pruning than where the roots only were pruned; and odds of 44 to 1 that a higher yield was obtained with no pruning than with both tops and roots pruned, the latter being the commercial practice. Odds in the last case are high enough that the difference can be considered to be statistically significant, and the practice of leaving the plants unpruned can be recommended as giving higher yields than pruning the tops and roots.

Table 2. Effect of pruning onion plants at transplanting time on the bushels of onions per acre

Treatment	U. S. No. 1 (Jumbo and medium sizes)						Total yield					
	1933*	1934	1935	1936	1937	Av.	1933	1934	1935	1936	1937	Av.
Tops and roots both pruned	222	221	99	245	432	244	301	298	164	317	484	318
Tops only pruned	173	274	143	251	451	258	254	370	221	321	508	335
Roots only pruned	258	191	134	298	417	260	343	270	200	361	497	334
No pruning	296	229	115	298	459	279	399	316	178	350	528	354

*Year of harvest.

Table 3. Effect of pruning onion plants at transplanting time on their relative rank as based on yield*

Treatment	U. S. No. 1 (Jumbo and medium sizes)						Total yield					
	1933†	1934	1935	1936	1937	Av.	1933	1934	1935	1936	1937	Av.
Tops and roots both pruned	3	3	4	4	3	4	3	3	4	4	4	4
Tops only pruned	4	1	1	3	2	3	4	1	1	3	2	2
Roots only pruned	2	4	2	1	4	2	2	4	2	1	3	3
No pruning	1	2	3	2	1	1	1	2	3	2	1	1

*Highest yield ranks 1.
†Year of harvest.

Table 4. Bushels of onions per acre obtained by setting plants of different sizes

Size of plant	U. S. No. 1 (Jumbo and medium sizes)							Total yield						
						Average							Average	
	1933	1934	1935	1936	1937	All seasons	Last 4 seasons	1933	1934	1935	1936	1937	All seasons	Last 4 seasons
Small	163	91	80	329	290	191	198	216	153	158	397	364	257	268
Medium	193	211	97	364	383	250	264	256	288	165	434	460	321	337
Large	361	119	74	328	298	236	205	530	383	159	475	479	405	374

Size of Plant

For four consecutive seasons, 1933-34 to 1936-37, inclusive, the use of medium size plants has been the most productive procedure of the three tested in this experiment (Table 4). When the results of all five seasons, 1932-33 to 1936-37, are averaged the medium sized treatment still excels. The average yield of U. S. No. 1 onions of 250 bushels per acre from this treatment is significantly higher than the 191 bushels from the small plant treatment. However, it is not significantly greater than the large plant treatment, but the reason for this is the exceptionally high yield obtained in the first season, 1932-33, from the plats planted with large plants. If this first season is omitted from the final average the medium sized plant treatment has an average of 264 bushels of U. S. No. 1 per acre, the small

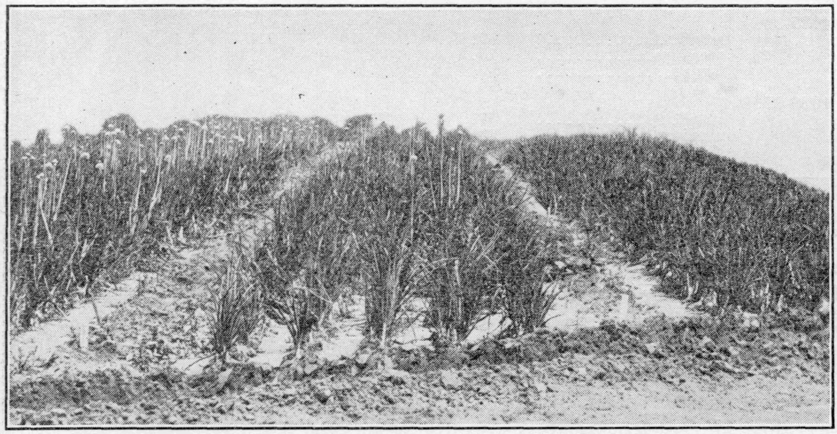

FIG. 3. Onions in size of plant experiment several weeks before harvest in the 1935-36 season. Notice seedstem formation. Plat on left had been planted with large plants; plat in center with medium sized plants, and one on right with small plants. The background has been blocked out to show these differences.

plant treatment has an average of 198 bushels. This period of years gives the medium sized plant treatment a significant increase in yield over the treatment using large plants, and an increase of 66 bushels of U. S. No. 1 bushels per acre over the small plant treatment.

When total yields in each of the seasons are studied it is seen that on an average the large plant treatment is significantly ahead of the medium sized plant treatment, which in turn is decidedly ahead of the small plant treatment. It is normal for large plants to produce large bulbs and hence heavier total yields. The danger to the commercial grower in using the large plant is that too high a percentage of the bulbs may be culls in the form of splits, doubles, and seedstems (Table 5). Sudden spells of sub-freezing temperatures such as occurred in 1932-33 are likely to cause large numbers of splits and doubles, irrespective of the size of plant, while prolonged periods of sub-normal temperatures (but not necessarily below-

Table 5. The effect of plant size at transplanting time on the percentages of the total yield falling in the various grades

Season	Size of plant	Jumbos	U.S. No. 1	Boilers	Culls	Seeders*
1932-33:						
	small	0	75.5	6.0	18.5	
	medium	1.6	73.8	4.7	19.9	
	large	4.2	68.0	4.9	27.0	
1933-34:						
	small	0	59.5	30.1	10.4	
	medium	0	73.3	12.8	13.9	
	large	0	31.1	4.4	64.5	
1934-35:						
	small	0	50.6	46.2	3.2	
	medium	0	58.8	35.8	5.5	
	large	0	46.3	26.9	26.9	
1935-36:						
	small	9.8	73.0	7.1	10.1	0.8
	medium	15.2	68.7	3.7	12.4	2.8
	large	9.1	60.0	2.5	28.4	12.4
1936-37:						
	small	1.9	78.4	13.9	5.8	0.3
	medium	3.0	80.2	6.7	10.0	2.4
	large	7.3	54.9	2.5	35.3	20.7

*In the seasons of 1935-36 and 1936-37 there were abnormally large numbers of seeders, and hence a separate record was made of them. However the percentage of culls given for these two seasons already include the seeders, which constitute one type of cull onions.

freezing) during the winter months, as in the seasons of 1935-36 and 1936-37, are likely to cause large numbers of seedstems. Large plants seem most susceptible to these adverse conditions; medium sized plants are less susceptible, and small plants least susceptible (Table 5 and Fig. 3). The reason why the large plants did so well the first season is probably explained in part at least by their considerably smaller size that year (Table 1). Had they been larger as they were in following years, there might have been more culls than there were, and the treatment would not have made the promising showing credited to it. As it is, the plants in the large plant treatment of the season 1932-33 corresponded really to the medium sized plants in following years, and hence supports the idea that plants of that size are the most desirable.

Rate of Seeding

This experiment was, as explained under "Methods Employed," a direct outcome of the size of plant experiment. As also explained the treatments were necessarily varied each year so that it is impossible to compare results from year to year on exactly the same treatments. However, as can be seen from Table 6, some treatments in each year were very nearly the same. Even had it been possible to duplicate the treatments exactly each year, variations would still undoubtedly have actually existed, as the percentage of germination is not likely to be the same every year. Even with seed having the same viability, stands are very likely to vary under field conditions, due to different climatic conditions, variations in soil, in irrigation, etc., which occur from year to year.

Table 6. Numbers of plants produced, acres which can be planted, and weight and percentages of plants as affected by the rate of sowing in seed bed

Year	Pounds of seed per acre	No. of plants per acre of seed bed	Would plant acres at*		Weight of 100 plants (grams)	Percentages of different sized plants				
			14″ rows	16″ rows		Very small	Small	Medium	Large	Very large
1934	6.6	418,770	3.7	4.3	757.9	....	28.5	42.0	29.5	0.0
	12.6	1,065,240	9.5	10.7	485.5	....	31.0	59.0	10.0	0.0
	23.0	1,904,760	17.0	19.4	247.9	....	55.0	44.0	1.0	0.0
1935	4.3	261,360	2.3	2.7	875.0	0.0	14.5	48.0	34.0	3.5
	7.4	500,940	4.5	5.1	705.8	4.0	18.5	59.0	17.0	1.5
	9.9	707,850	6.3	7.2	510.9	7.5	30.5	53.0	8.0	1.0
	16.9	1,067,220	9.5	10.9	357.3	10.5	34.0	47.5	8.0	0.0
	26.5	2,058,210	18.4	21.0	320.7	12.0	68.0	18.5	1.5	0.0
	38.5	3,332,340	29.8	34.0	220.0	28.0	63.0	9.0	0.0	0.0
1936	1.9	70,785	0.6	0.7	1200.1	0.0	8.5	45.0	40.0	6.5
	2.6	100,188	0.9	1.0	1124.6	0.0	9.5	45.0	42.0	3.5
	5.5	325,611	2.9	3.3	1145.4	0.0	11.5	46.5	38.5	3.5
	7.4	514,008	4.6	5.2	742.9	2.5	10.5	72.0	14.5	0.5
	16.7	1,058,508	9.5	10.8	329.8	13.0	36.5	50.5	0.0	0.0
	36.4	2,293,434	20.5	23.4	193.8	18.5	66.5	15.0	0.0	0.0

*Assuming plants are spaced 4 inches apart in the row.

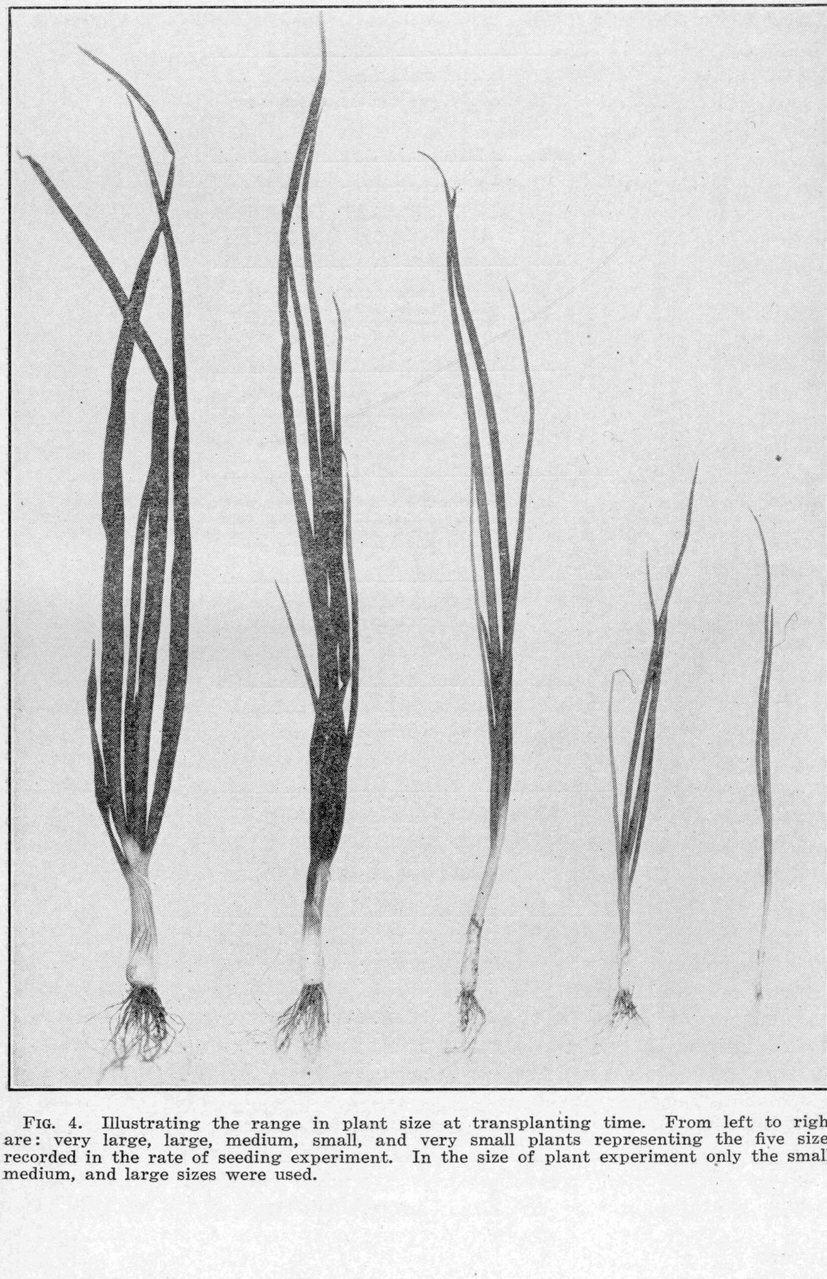

FIG. 4. Illustrating the range in plant size at transplanting time. From left to right are: very large, large, medium, small, and very small plants representing the five sizes recorded in the rate of seeding experiment. In the size of plant experiment only the small, medium, and large sizes were used.

Weight of Plant as Affected by Rate of Seeding: There is a distinct relationship between the pounds of seed sown per acre and the weight of the plants produced. As the rate of seeding increases, the weight of plants decreases. This condition occurred in each of the three years (Table 6). While most rates of seeding will result in plants of nearly all sizes (Fig. 4), the percentage of the different sizes varies with the rate. When the seed is sown thinly, at rates ranging from less than 2 pounds up to around 6 or 7 pounds per acre, the percentage of very small and small sized plants runs low, and that of the large and very large plants runs comparatively high. On the other extreme, when the rate of seeding exceeds 30 pounds per acre (as one treatment did in 1935 and 1936) the percentage of very small and small plants runs high, and there will be very few or no large plants at all.

Variation in Plant Size as Affected by Rate of Seeding: From the size of plant experiment it is known that the medium sized plant is the most dependable one to transplant. At rates of seeding up to around 20 pounds per acre the percentages of medium sized plants are usually in the neighborhood of 45 to 60, occasionally higher. As soon as the rate of seeding exceeds about 20 pounds per acre the percentage of medium sized plants drops well below 50. In 1935, 26.5 pounds of seed per acre resulted in 18.5 per cent medium sized plants, and only 1.5 per cent large plants, the remainder being small and very small plants. In the same year 38.5 pounds of seed per acre resulted in only 9.0 per cent of medium sized plants, not a single large or very large plant, but 63 per cent small plants and 28 per cent very small plants. The latter are practically worthless. In 1936, 36.4 pounds of seed per acre resulted in no large or very large plants, only 15 per cent medium sized plants, but 66.5 per cent small plants and 18.5 per cent very small.

Number of Acres Set Out from an Acre of Seedbed: The number of acres which can be set from one acre of seedbed increases with the number of pounds of seed per acre sown (Table 6). At a rate as low as 1.9 or 2.6 pounds per acre not enough plants can be produced to plant an acre. At rates of over 30 pounds per acre, it is theoretically possible, if every seedling is used, to plant out 20 acres or more from one acre of seedbed. The highest rate that still produces 45 or more per cent of medium sized plants is around 17 pounds of seed per acre, and such a rate will produce sufficient plants to set out approximately 10 acres with rows spaced 14 inches and nearly 11 acres with rows at 16 inches. Such acreages are considered satisfactory by most onion growers.

Direct Field Sowing versus Transplanting

On the basis of the three years in which yield records were collectible from both treatments in this experiment, the transplanting method resulted in an average yield of 124 bushels of U. S. No. 1 onions as compared with only 65 bushels from the direct field sown method (Table 7). In total yields the results were still in favor of the transplanting method although the difference was not as great. In the season of 1932-33 a serious freeze in February killed all the plants in the direct field sown plats. Planted later than those in the regular seedbed, they were smaller and evidently could not withstand the low temperatures. The yields in the transplanted plats were not recorded that year, but the stands were excellent, and all signs pointed towards high yields. On the basis of nearby plats in other experiments which had been handled very similarly, the total yield of all grades should have been around 375 bushels per acre in that year.

Table 7. Comparison of direct field sowing and transplanting (bu. per A.)

Method of planting	U. S. No. 1 (Jumbo and medium sizes)					Total yield				
	1932*	1933	1934	1935	Av.‡	1932	1933	1934	1935	Av.‡
Direct field sown...	104	......	59	31	65	388	......	113	56	186
Transplanted......	76	......	185	110	124	171	375†	272	168	204

*Indicates year of harvest.
†Estimated, never actually measured.
‡Average does not include 1933.

Only in the first season, 1931-32, did the direct field sown treatment result in higher yields than the one in which the plants were transplanted, and even then the difference was not statistically significant in the U. S. No. 1 yield. In the total yield the direct field sown treatment exceeded the transplanted by 217 bushels per acre. However, the records show that of the 388 bushels in the total yield of the direct field planted method that year, 248 bushels were misshapen, and in addition there were over 19 bushels of other types of culls. The cull yield constituted 68.9 per cent of the total yield. In the transplanted plats only 11 of the 171 bushels in the total yield or 6.4 per cent were in the cull pile. It was because of such results as these that the plats in the direct field sown method were planted a month later than the plats which were transplanted. Such a procedure reduced the percentage of culls decidedly. However, yields were also reduced. While direct field sowing saves the time, labor, irrigation, water and land put into a seedbed, it hardly compensates for the loss in yield normally to be expected. In some years there may be a complete loss through this method, because of the small plants being killed by a freeze.

Because of the intensive methods, including the use of fertilizer, and water under irrigated conditions, it is more efficient to have good uniform stands. This is hard to obtain when the seed is sown directly in the field, unless it is sown thickly. To do this necessitates thinning, a slow and costly job which usually does not result is as uniform stand as when the plants are set out by transplanting. In some sections there is a market for plants removed by thinning, a situation which may make direct field sowing profitable, but in the Winter Garden area there is rarely if ever such a market.

Width of Row

In four consecutive seasons, 1933-34 to 1936-37, onions planted in 14-inch rows yielded more per acre than did onions planted in 16-inch rows. In the season of 1932-33 the reverse was true. When the five seasons are averaged, the 14-inch treatment resulted in 257 bushels of U. S. No. 1 onions per acre as compared with 237 bushels from the 16-inch treatment (Table 8). When total yields are considered for this same five-year period the yield of 343 bushels per acre from the 14-inch treatment exceeded the yield from the 16-inch treatment by 39 bushels. Although a two-inch difference in the distance between rows does not on the average make a tremendous difference, it does at the same time seem to result in a definite trend towards higher yields and hence is a profitable practice. In some irrigated sections onions are planted in 12-inch rows; possibly such a practice would be still more productive.

Frequency of Irrigation

At first glance the results obtained by varying the frequency of irrigation may seem inconsistent. Unfortunately various uncontrollable factors influence such an experiment one way or another and hence the results seem inconsistent, while in reality they are not. It is obvious that rainfall cannot be prevented, and hence precipitation usually becomes a factor in an outdoor experiment continuing over a period of five to six months. Onions are subject to thrips, an insect which sucks the juices from the leaves of the plant. Such a pest undoubtedly affects the water requirements of the plant. Rainfall and thrips were both variable factors in the irrigation experiments and of the two, thrips were by far the more uncertain factor, because precipitation could be partially adjusted, while the amount of damage from thrips could not be definitely ascertained. No attempt was made to compensate for thrips, but because of their presence in the last two years of the irrigation experiments, a knowledge of how often to irrigate when they are present in great numbers was obtained.

In 1931-32 and 1932-33 thrips were not a serious factor in the onion fields. Only three treatments were tried in the first season and the one in which there were fewest and least frequent irrigations (based on 1.75 inches of accumulated evaporation) resulted in the highest yields—127 bushels of U. S. No. 1 onions as compared with 107 bushels for the treatment of medium frequency, and 101 bushels for the most frequent one (Table 9). Total yields resulting from the same treatment were, of course, larger but had about the same relationship to each other.

In the following season, 1932-33, the relationship of these three treatments was still approximately the same, although all yields were decidedly larger that year, and the yield of U. S. No. 1 onions from the treatment based on 1.75 inches accumulated evaporation was 71 bushels greater than the next treatment, namely, the one based on 1.25 inches evaporation. Besides the three original treatments, there was in 1932-33 a still less frequently irrigated treatment based on an accumulated evaporation of

Table 8. Effect of width of row on yield (bu. per A.)

Width of row (inches)	U. S. No. 1 (Jumbo and medium sizes)						Total yields					
	1933*	1934	1935	1936	1937	Aver.	1933	1934	1935	1936	1937	Aver.
14......................	251	145	105	364	419	257	326	307	164	426	491	343
16......................	270	140	90	307	378	237	329	274	133	353	433	304

*Year of harvest.

Table 9. Effect of the frequency of irrigation on yield (bu. per A.)

Accumulated evaporation (inches)	Number of irrigations					U. S. No. 1 (Jumbo and medium sizes)					Total yield				
	1932	1933	1934	1935	Av.	1932	1933	1934	1935	Av.	1932	1933	1934	1935	Av.
0.75..........................	16	16	13	16	15	101	171	188	224	171	200	259	258	283	250
1.25..........................	9	8	7	8	8	107	181	222	231	185	209	256	299	287	263
1.75..........................	6	5	5	6	6	127	252	190	171	185	222	317	274	213	256
1.75, later 1.25...............	......	8	6	7	7	......	314	176	221	237	......	376	241	273	297
2.25..........................	......	3	2	5	3	......	266	107	145	172	......	338	190	193	240
2.25, later 1.25...............	......	6	4	7	6	......	267	131	206	201	......	322	196	253	257
Precipitation during period from transplanting to harvest......	3.61	5.73	5.93	6.24	5.38										

Table 10. Effect of delayed initial irrigation and delayed planting on the bushels of onions per acre

Treatment	U. S. No. 1 (Jumbo and medium sizes)						Total yield					
	1933	1934	1935	1936	1937	Aver.	1933	1934	1935	1936	1937	Aver.
Irrigated immediately......	205	139	150	329	396	244	261	212	204	388	468	307
Irrigation delayed.........	181	120	149	362	341	235	219	193	208	413	413	289
Planting delayed; irrigated immediately............	188	122	176	303	313	215	213	197	251	359	377	279

2.25 inches. The yield of U. S. No. 1 onions from the plats irrigated on this schedule was 266 bushels per acre, higher by 14 bushels than the high yield from the 1.75-inch plats mentioned above. The results of these two seasons strongly indicated that too-frequent irrigation may reduce yields.

However, the additional treatments in the second season indicated that the age of the crop also needs to be considered. These treatments (1.75 inches, and 2.25 both changed to 1.25 inches when onions began bulbing) were designed to discover if the onion needs more water after it begins to bulb. As Table 9 shows, the treatment based on 1.75 inches accumulated evaporation, and later changed to 1.25 inches, resulted in the highest yield of U. S. No. 1 onions, as well as in the highest total yield in the entire experiment that year. The treatment which at first was irrigated at the 2.25-inch rate did not respond so noticeably to the more frequent irrigation towards the end of the season, the yield being practically the same as that from the plats irrigated at the 2.25-inch rate all through the season.

The seasons of 1933-34 and 1934-35 were characterized by severe thrips infestations. In both seasons the plats irrigated at a frequency based on 1.25 inches accumulated evaporation, had the highest yields of U. S. No. 1 onions, as well as total onions (Table 9). In 1933-34, the treatment based on 1.75 inches was second in yield and the one based on 0.75 was third. In the 1934-35 season, which had a still worse infestation of thrips, the treatment irrigated at an accumulated evaporation frequency of 0.75 inches was second and the one based on 1.75 inches ranked fifth. Lowest yielding plats in both these seasons were those being irrigated on a frequency of only 2.25 inches accumulated evaporation. The onions in these plats were observed to suffer for water. In the first two seasons when thrips had been negligible, it had been impossible to pick out the least irrigated plats by the appearance of the foliage. The only plats which could be pointed out in those first two seasons were the ones receiving the most water, as the foliage of the onions had a distinct yellowish cast and lacked the deeper green color seen in the onions of the other plats. Presumably this color was due to lack of nitrogen, which undoubtedly was being leached out of the sandy soil by the frequent waterings.

The results of all four seasons indicate that irrigations as frequent as those necessitated by an accumulated evaporation frequency of 0.75-inch, giving 13 to 16 irrigations in a season will not result in the highest yields, even in years of severe thrips infestation. In a very bad year, such as the season of 1934-35, such a treatment may result in higher yields than treatments calling for seven or less irrigations. In any year frequency of irrigation under commercial conditions should depend on rainfall, thrips infestation, and any factor (such as possibly pink root) which affects the water requirements of the plant. In years which have no upsetting factor, there should usually be no more than 5 to 8 irrigations, spaced at intervals of 3 to 5 or more weeks at first, and stepped up to around a week to 2 weeks apart after bulbing begins.

Delayed Initial Irrigation

Because a period of 10 to 12 days at the beginning of a growing season of around 20 weeks is a rather short time to establish a difference in development that can be determined at the end of the growing season, it might be expected that results would not always be clear-cut nor always the same. As Table 10 shows, such an expectation is justified. However, a close study of the results combined with a consideration of the weather conditions, particularly as to rainfall, in that brief initial period reveals that the data have some understandable trends. Table 11 records the precipitation during those early days of each season's experiment, and indicates that differences due to delayed initial irrigation can be established when rainfall is not a factor.

Table 11. Total precipitation during the period of delayed initial irrigation and its effect on yield

Season	Total precipitation, inches	Supplementary notes	Effect on yield
1932-33	0.19	Distributed over last 6 days of a 15-day period*	Plats irrigated immediately gave highest yields
1933-34	0.00	Soil dry	Plats irrigated immediately gave highest yields
1934-35	0.13	Rained on 4 scattered days	Plats irrigated immediately did **not** give highest yields
1935-36	0.31	Distributed over 8 days	Plats irrigated immediately did **not** give highest yields
1936-37	0.00	Soil very dry	Plats irrigated immediately gave highest yields by largest margin in 5 years

*Rain prevented the completion of treatments at the end of 12 days as originally planned.

In the third and fourth seasons when rain fell intermittently throughout the period immediately following transplanting, the onions in those plats receiving water at once did not apparently have any advantage over the onions in the other treatments, or if they did, it was not reflected in heavier yields four months later. Rainfall is a more natural process than surface irrigation and because of the favorable conditions (such as lower temperatures, higher humidity) which usually accompany it, newly transplanted plants generally respond to it. In the first season also there was a relatively long period of rainy weather, but it did not start until the plants had been out nine days in a dry soil, and thus presumably came too late to offset the disadvantage suffered by the plants transplanted without irrigation.

Why the plants which were stored for ten days before being set out in 1934 gave higher yields the following April than the plants in the other treatments is not understood. It is known from long observation, however, that onion plants stand up under such storage better than most vegetable plants, and evidently because of some unknown factor they even had an advantage in that season.

In a section such as the Winter Garden Region of Texas where dry weather conditions are very likely to prevail at transplanting time, the sensible practice would seem to be to water as soon as possible after transplanting. Only in one season out of the five during which this experiment was being conducted, did delayed irrigation result in a noticeably higher yield than where the plants received water immediately, and in that season, 1935-36, it rained 8 days out of the 9 that irrigation water was being withheld. Differences in yield in favor of immediate irrigation may not be great. In five years the average advantage in terms of U. S. No. 1 onions was only 9 bushels, and in terms of all grades including culls it was 18 bushels (Table 10). These are not significant differences. In the last season, however, the immediately irrigated treatment had an advantage of 55 bushels of U. S. No. 1 onions, and exactly the same advantage in the total yield also.

Fertilizer Placement

Although this experiment has only been conducted three years and the results do not show the same differences each year, they do show the same trend. Summarizing the results for the three years, onions receiving 600 pounds of 6-12-6 fertilizer in a 4-inch band beneath the row had an average yield of 265 bushels of U. S. No. 1 onions as compared with 227 bushels from the onions planted in plats in which the same amount of fertilizer was broadcast (Table 12). If it had been possible to distribute the fertilizer

Table 12. Method of distributing fertilizer (600 lbs. 6-12-6)

Method of application	U. S. No. 1 (Jumbo and medium sizes)				Total yield			
	1935*	1936	1937	Av.	1935	1936	1937	Av.
Placed	101†	323	372	265	179	387	452	339
Broadcast	96	234	359	227	168	301	423	297

*Year of harvest.
†Bushels per acre.

in the "placed" plats with a machine which in the same operation had made the ridges along which the onion plants were later set out, these results, it is believed, would have been even more clear-cut. In several instances the ridges did not come exactly over the furrow in which the fertilizer had already been placed. At the end of a plat the operator had perhaps deviated as little as an inch or two in preparation for turning around, and yet for a number of weeks in the early life of the transplanted onions this deviation could be seen because of the poorer growth shown by the plants. Such plants were probably at a greater disadvantage than the plants in the broadcast plats, for there the plants did have some fertilizer adjacent to their roots, while the plants in the offset rows had none. Although such instances were fortunately very few they undoubtedly tended to reduce the yields in the "placed" fertilizer plats.

RELATION TO COMMERCIAL PRACTICE

Since the results of the experiments discussed above are known, the question arises as to how and to what extent they can be applied to commercial practices. Undoubtedly some promising treatments are more adapted to practical commercial conditions than are others. Some treatments may have more or less a relationship to other treatments or be affected by or have a bearing on other practices. It is with such points in mind that the following comments are made.

Pruning the Plants: From the results obtained over a period of five years, it would seem that it does not matter a great deal whether the plants are pruned or not, except that there is a slight trend towards heavier yields from unpruned plants. Omitting the pruning customary to commercial practice saves a negligible amount of time, if any, when the plants are being pulled from the seedbed preparatory to transplanting. Unpruned plants are not favored by onion workers, as the extra foliage on each plant hinders the procedure of setting out. It is possible that a grower who leaves his plants unpruned may have to pay a slightly higher cost to have them set out. However, as results in Table 3 indicate, it is possible in some seasons that a slightly higher cost on this account may be repaid several times over by the additional yields obtained.

Size of Plant and Rate of Seeding: Although the results indicate that the size of the plant at transplanting time may have considerable effect on yield, actual experience in grading the plants indicates that sorting out the plants of desirable size is entirely impractical because of the time and expense involved. The most practical solution seems to be to sow the seedbed at such a rate as to obtain the highest percentage possible of medium sized plants without too great a sacrifice in total production of plants. Most growers are satisfied if they can set out ten acres of onions from one acre of seedbed. According to the records of these experiments, around 17 pounds of seed per acre of seedbed should normally give very satisfactory results.

This problem can be examined from another angle. Suppose a grower plants around 36 pounds of seed per acre and obtains enough plants to set out around 20 acres of plants, a record very closely approximating the last treatment at the Station in 1936. According to that same record only 15 per cent of the 20 acres would be planted to medium sized plants (about 3 acres); the remainder (17 acres) would be set to very small and small plants.

Had the 36 pounds of seed been distributed in two acres of seedbed, the expense would, of course, have been increased somewhat. However, a grower would then be more likely to have 45 to 50 per cent of his plants of medium size, with possibly a few large ones, and a few of the smaller sizes. He would still be able to plant about 20 acres altogether. Assuming that he has only enough medium sized plants to plant 45 per cent of the acreage, which amounts to nine acres, he would then have eleven acres in the other, mostly smaller sizes.

Planting the seed on one acre results in 17 acres planted with small plants, and planting the seed on two acres results in eleven acres of small plants, a difference of six acres. In these experiments, the small sized plants (excluding the very small plants) yielded on an average for the last four seasons only 198 bushels of U. S. No. 1 onions per acre as compared with 264 bushels for the medium sized plants. This difference on six acres would amount to 396 bushels of U. S. No. 1 onions, which in any normal year would pay for the extra seedbed a number of times over. Moreover, the use of the very small plants would undoubtedly tend to increase still more this estimated difference.

Direct Field Sowing vs. Seedbed and Transplanting: Under intensive irrigated conditions transplanting, according to the results of the experiment reported herein, would seem to be the most profitable procedure. However, where there is a ready sale for plants, direct field sowing might work out very well. Then the seed could be sown thickly enough to enable a grower to have an excellent uniform stand after thinning. The sale of the plants removed at thinning would pay for that operation. Direct field sowing, while it saves the labor of transplanting, does not under normal conditions result in as much economy as it might appear at first. Instead of an acre of seedbed one has around ten acres of plants requiring seedbed handling. With the direct field planting method one almost always has to be prepared for the cost of thinning, or if that is avoided by sowing thinly then the yield of bulbs is very likely to be considerably less than it would be if the transplanting method had been followed. There is also the danger from freezing with the later planted direct field sown method.

Width of Row: Since the results of the spacing experiment together with the spacing experiments in California (3), Utah (10), and Montana (7) all indicate that close spacing increases yields, it would seem that close spacing would be the most profitable practice under irrigated conditions. Experience at the Station has shown that very satisfactory results may be expected with 14-inch rows, and sections in South Texas which practice the border method of irrigation often use 12-inch rows with success. The spacing within the row is normally 3½ to 4 inches. Of course, other factors besides yield enter into the problem of spacing. Twelve-inch rows required smaller footed mules than 16-inch rows, and because the foliage is going to meet sooner across the rows, cultivation may have to cease earlier. Such factors always need consideration in any individual case.

Irrigation. No definite rule can be laid down regarding the frequency of irrigation. The data presented indicate that the initial irrigation should be as soon as possible after the onions have been transplanted. After that, there is no question but that the time to irrigate will depend on a number of factors such as the type of soil, the amount of rainfall, condition of the plants, the presence of insects, diseases, and so on. The experiments seem to show that too frequent irrigations will reduce yields. What constitutes over-irrigation will vary from one year to the next. In a year of severe thrips infestation, it is absolutely necessary to irrigate more frequently than one would in a year when thrips are scarce (other factors being the same), unless one is satisfied with very low yields. Over-irrigation in any year is likely to be associated with a characteristic yellowish green color of the foliage. In years of severe thrips infestation or in the presence of other troubles, such an appearance of the foliage may be difficult to determine, but usually it exists. Under-irrigation is not nearly so easy to determine. In those years when thrips were practically absent from the experiments it was impossible to distinguish any differences between the foliage of lesser irrigated treatments. In such a treatment as the one based on 2.25 inches of accumulated evaporation, the soil for a week or more before the time to irrigate would seem to be perfectly dry, yet the foliage looked healthy and the yields at harvest time were above expectations. Had one been irrigating on the basis of soil appearance, the plats would have been irrigated much more frequently.

Normally five to eight irrigations are sufficient on the sandy loam soils in the Winter Garden area between transplanting time and harvest in a year when thrips are not a serious factor. Such irrigations are usually necessary every six to ten weeks until the onions begin to bulb after which they need to be one to two weeks apart. In a year of heavy thrips infestation, if a frequency of irrigation corresponding to 1.25 inches of accumulated evaporation is followed, than the onions will be irrigated about every three and a half to five weeks in the early life of the crop followed by waterings every one to two weeks after bulbing begins.

Fertilizer Placement: From the results of the simple experiment reported upon herein, it would seem that placement of the fertilizer in a 4-inch band below the ridges in which the onions are transplanted is a desirable and profitable practice. The chief need is a machine that will make the ridges and distribute the fertilizer all in one operation. Since work elsewhere (6, 8, 11) has indicated that with most vegetable crops the exact position of the fertilizer is important, it is possible that further refinements have yet to be made in the placement of fertilizer for onion plants. Regardless of this point, however, it is believed a profitable step could even now be made in the direction of fertilizer placement providing a grower has suitable equipment.

SUMMARY

1. Results were secured from five years of transplanting plants treated in one of the following ways: (a) tops and roots both pruned, (b) tops only pruned, (c) roots only pruned, (d) unpruned. These gave definitely higher yields for treatment (d) unpruned than for treatment (a) severe pruning. No difference could be distinguished between treatments (b) and (c) which appear to be between the other two in yield.

2. Medium ("pencil") sized plants are the most dependable plants to set out, usually resulting in the highest yields. Large plants may occasionally give very high yields, but in general result in too many splits, doubles, and seedstems to make their use profitable in most seasons.

3. As the number of pounds of seed sown per acre is increased the average weight and size of the resulting plants decreases.

4. With most rates of seeding except the extreme light or heavy, all sizes of plants are usually produced. With heavier rates of seeding there are more small plants. Up to 20 pounds of seed per acre the medium sized plants remain around 45 to 50 per cent of the crop, but above this rate the percentages of small and very small plants increase rapidly at the expense of the medium sized ones, and the yield of this valuable size becomes unprofitable.

5. The number of acres which can be set from one acre of seedbed if plants of all sizes are used increases with the number of pounds of seed sown to the acre.

6. Direct field sowing under irrigated conditions rarely results in as high yield as transplanting from a seedbed. The yield is usually sufficiently higher than the latter practice to make it easily the more profitable of the two, unless because of special conditions such as a ready sale for plants removed by thinning, additional factors favor direct field sowing.

7. Fields planted in 14-inch rows will normally yield more than those in 16-inch rows.

8. Over-irrigation should be avoided as it usually reduces yields. It should be understood that a frequency of irrigation that is desirable under one set of conditions may result in over-irrigation under another.

9. Increasing the frequency of irrigation as soon as the onions began bulbing, from a rate based on 1.75 inches of accumulated evaporation to one based on 1.25 inches, increased yields decidedly.

10. In years of heavy thrips infestation, a frequency based on 1.25 inches of accumulated evaporation throughout the entire season resulted in the highest yields.

11. In the seasons when no rain fell to interfere with the treatments, highest yields were obtained from those plats which were irrigated immediately after they had been set out. In such seasons a delay of around ten days in applying the water reduced the yields.

12. Placing 600 pounds per acre of 6-12-6 fertilizer in a 4-inch band, one to two inches below the ridge into which the onion plants were transplanted, resulted in higher yields in every year of three years tried, than where the same amount of fertilizer was broadcast previous to the making of the ridges.

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